Intake and chewing behavior of steers consuming switchgrass preserved as hay or silage[1]

J.-M. Luginbuhl*,†,‡,[2], K. R. Pond¶, J. C. Burns*,†,§, and D. S. Fisher#

†Crop Science Department, *Animal Science Department, ‡Interdepartmental Nutrition Program, and §USDA, ARS, North Carolina State University, Raleigh 27695-7620; ¶Department of Animal Science and Food Technology, Texas Tech University, Lubbock 79409; and #USDA, ARS, Watkinsville, GA 36677

ABSTRACT: Effect of preservation method on intake and chewing behavior was examined using a first, late vegetative harvest (mid-June) of Kanlow switchgrass (*Panicum virgatum* L.). For silage (**S**), forage was harvested with a commercial field chopper (1.5 to 4 cm average chop length) and ensiled directly in silos 1.2 m in diameter and 3.6 m in height. For hay (**H**), forage was harvested with a flail-chopper (7 to 15 cm average chop length) and cured as hay in a drier at 77°C. Diets of H and S were fed to six Hereford steers (338 ± 5 kg) in a single crossover experiment. Chewing behavior was monitored for 4 d with a computerized system. At feeding, H was higher in DM and contained greater concentrations (DM basis) of NDF, CP, and hemicellulose, but lower concentrations of ADF and cellulose, and had lower in vitro DM disappearance values. Steers fed S had higher intakes of DM ($P < .02$) and NDF ($P < .04$) and consumed less water from the water supply ($P < .01$) than animals fed H. However, total amount of water (from water supply and feed) consumed per kilogram of DMI did not differ between diets. Crude protein intake was similar between diets. Preservation method had no effect on eating time, number of boli ruminated, bolus duration, and number of rumination chews per bolus. Steers fed S made fewer eating chews ($P < .10$) and ruminated for a longer time ($P < .05$) while making a greater number of rumination chews ($P < .04$) than steers fed H. Rumination intercycle time was slightly shorter in steers fed H ($P < .05$) than in steers fed S. When expressed per kilogram of NDF intake, steers fed S spent less time eating ($P < .03$) and made fewer eating chews ($P < .02$) than steers fed H; however, rumination time, number of rumination chews, and number of boli ruminated were not affected by preservation method. Steers fed S ingested feed at a greater rate ($P < .03$), excreted smaller fecal particles ($P < .03$), had meals of shorter duration ($P < .06$), spent less time eating during main meals (meals following feed distribution: $P < .05$), had more rumination periods ($P < .01$), and a shorter morning ($P < .06$) latency time (interval between end of main meal and onset of rumination) than steers fed H. These results indicate that preservation method with its concomitant differences in chop length affected forage chemical composition and voluntary intake, and that differences in chewing behavior occurred mostly during eating.

Key Words: Feeding Behavior, Hay, *Panicum virgatum*, Silage, Steers

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Introduction

Switchgrass (*Panicum virgatum* L.) has great potential as a livestock feed when either grazed (Burns et al., 1984) or conserved as hay (Vona et al., 1984; Burns et al., 1985). However, Kanlow switchgrass is difficult to dry as hay in the humid eastern United States; its coarse stems can require up to 5 d for curing. The potential to conserve switchgrass as silage directly after cutting or after a short wilt has been evaluated. The best animal performance results were obtained from ensiling the forage directly (Burns et al., 1993).

This study was conducted to compare the effects of preserving switchgrass when ensiled directly or cured as hay on voluntary intake and chewing behavior of growing steers.

Materials and Methods

Forage and Preservation Methods. A well established stand of Kanlow switchgrass served as the forage

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[2]Correspondence: phone: (919) 515-8743; fax: (919) 515-5855; E-mail: jean-marie_luginbuhl@ncsu.edu.

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source. Foliage from the previous year was burned off in February and the stand was fertilized in March with approximately 90 kg nitrogen/ha. A first, late vegetative cutting was harvested in mid-June and either ensiled directly or cured as hay. Forage for both treatments was cut with a mower-conditioner at approximately 1030. Then, forage for the hay treatment was harvested with a flail chopper (7 to 15 cm average chop length), blown into a self-unloading wagon, held until dry in a forced-air bulk dryer (Burns et al., 1997) with an incoming-flue air temperature of 77°C, and finally baled and stored as rectangular hay bales. Following mowing, forage for the silage treatment was winrowed, immediately chopped with a field chopper (1.5 to 4 cm average chop length), and packed into experimental silos. Each silo was constructed out of three fiberglass rings bolted together, making silos 1.2 m in diameter and 3.6 m tall. A 25.4-μm-thick cylindrical plastic liner tied at the bottom was fitted into each silo. Forage was packed into the silos by treading on the material and the top of each liner was tied and sealed. The silos remained sealed for at least 60 d before they were opened and the silage was fed to steers.

Animals, Feeding and Monitoring of Chewing Behavior. Six Hereford steers, averaging 338 ± 5 kg BW, were housed indoors in individual tie stalls and given ad libitum access to experimental diets in a crossover design. Steers had continuous access to water and trace mineral salt blocks (percentages: NaCl, 93 to 98; Zn, > .35; Mn, > .28; Fe, > .175; Cu, > .035; I, > .007; and Co, > .007; Morton Thiokol, Chicago, IL). Steers were acquired, retained, and used in compliance with federal, state, and local laws and regulations. Steers were treated for internal and external parasites (Ivermectin; Mariel, Division of Merck and Co., Rahway, NJ). Each experimental period consisted of 21 d, divided into the first 7 d for adjustment to diets and the last 14 d for intake estimates and chewing behavior measurements. Chewing behavior was monitored with an electronic system during the last 5 d of the intake phase, with jaw movements recorded continuously and stored on computer diskettes (Luginbuhl et al., 1987). The recording system did not differentiate prehensile from chewing jaw movements during eating. Salt blocks were removed during the monitoring of chewing behavior to minimize the recording of licking events. Water consumption was estimated by incorporating flow-meters in the water lines (Hersey Meter Co., Dedham, MA). Steers were fed a weighed amount of forage daily at 0900 and 1600 allowing for 15% feed refusal. Feed refused was removed and weighed before each feeding. Daily samples of hay fed and refused were thoroughly mixed then subsampled for laboratory analyses. Daily samples of silage fed and refused were preserved by freezing. Frozen samples were later thawed, thoroughly mixed, subsampled, and freeze-dried for subsequent laboratory analyses. Estimates of DM and NDF intakes were corrected for feed refused.

Table 1. Effect of preservation method on the chemical composition and in vitro dry matter disappearance (IVDMD) of switchgrass fed to steers

	Preservation method		
Item, %	Hay	Silage	SE[a]
DM	94.6	27.2	.03
NDF, % of DM	74.0	71.4	.12
ADF, % of DM	37.9	39.2	.20
Hemicellulose, % of DM	36.1	32.2	.08
Cellulose, % of DM	32.2	33.4	.24
Lignin, % of DM	4.9	5.0	.03
CP, % of DM	7.0	5.8	.14
IVDMD, % of DM	52.9	57.5	.56

[a]Standard error from the GLM model.

Laboratory Analyses. All samples were analyzed for DM (AOAC, 1990), NDF, ADF, cellulose, and permanganate lignin (Robertson and Van Soest, 1981). Total N was determined using an autoanalyzer (AOAC, 1990) and multiplied by 6.25 to estimate CP. In vitro dry matter disappearance (**IVDMD**) was determined on diet samples by a modified two-stage technique (Tilley and Terry, 1963) as described by Burns and Cope (1974).

Representative samples of feces were taken daily during the last 5 d of each experimental period and preserved in a refrigerator at 3°C. At the completion of each 5-d collection, the daily fecal samples were thoroughly mixed, subsampled and frozen until analyzed. Fecal samples then were freeze-dried and dry-sieved (Burns et al., 1997) to determine particle weight distribution. The mean particle size was estimated from the sieving data by fitting the percentage cumulative weight distribution oversize to an exponential model (Fisher et al., 1988).

Statistical Analyses. Data were analyzed by the GLM procedure of SAS (1998) for a single crossover design (Lucas, 1948). The model consisted of sequence group (df = 1), steers within sequence group (df = 4), period (df = 1), diets (df = 1) and period × steers within sequence group (df = 4) as the residual error term.

Results and Discussion

Chemical Composition. The DM concentration of the silage differed drastically from that of the hay (Table 1); the latter value was high as a result of artificial curing. Concentrations (DM basis) of NDF and hemicellulose were greater in the hay, whereas ADF and cellulose concentrations were higher in the silage. Conservation method had no effect on lignin but resulted in a lower CP concentration for the silage. A greater IVDMD at 48 h was observed for the silage treatment. Switchgrass used in the present study contained low CP and high cell wall concentrations, consistent with results reported earlier (Burns et al., 1985). In addition, hemicellulose concentrations were similar to previously

Table 2. Effect of preservation method on the voluntary intake of switchgrass fed to steers

Item	Preservation method			
	Hay	Silage	SE[a]	$P > F$
DMI, kg/d	5.3	6.2	.2	.02
DMI, $g \cdot kg\ BW^{-1} \cdot d^{-1}$	15.8	18.1	.4	.02
Morning DMI, % of total[b]	39.6	43.3	1.1	.07
NDF intake, kg/d	3.9	4.5	.1	.04
CP intake, g/d	387.9	369.8	.01	.30
Water intake, L/d	22.0	10.6	.9	.001
Total water intake, L/d[c]	22.6	27.8	1.0	.03
Total water intake, L/kg DMI[c]	4.2	4.5	.16	.33

[a]Standard error from the GLM model.
[b]Intake between the morning distribution of feed (0900) and the removal of orts prior to the evening feeding (1600).
[c]Intake from feed and water supply.

reported values for subtropical grasses (Van Soest, 1973; Vona et al., 1984; Burns et al., 1993). These results are in contrast to the findings of Burns et al. (1993), who found no difference in CP concentrations and IVDMD values of late-boot and fully headed switchgrass harvested as hay or ensiled directly.

Voluntary Intake. Steers ingested a lesser proportion of their total daily intake following the morning than following the evening distribution of feed (morning: 41%; evening: 59%; data not shown); time allocated for feed consumption was 7 h (29%) following the morning feeding and 17 h (71%) following the evening distribution of feed. In an earlier study, Luginbuhl et al. (1989) reported that steers fed bermudagrass hay at 0900 and 2100 consumed 60% of their daily feed following morning feeding and the remainder at night. Feed distribution schedules imposed by the experimenter may shift the circadian pattern of feed consumption.

Intakes of DM ($P < .02$) and NDF ($P < .04$) were higher for steers fed silage than for those fed hay by .9 and .6 kg/d, respectively (Table 2). Nevertheless, DMI were relatively low. Steers consumed proportionately more silage than hay following the morning feeding ($P < .07$). Forage preservation method had no effect on CP intake because the greater ingestion of silage negated the effect of ensiling on CP concentration. As anticipated, steers fed hay consumed a greater quantity of water ($P < .001$) from the water supply than steers fed silage. Conversely, total water intake (water consumed from the water supply and water ingested as part of the feed) was greater for steers fed silage ($P < .03$) than for those fed hay. However, total water intake/kg DMI ingested did not differ between treatments.

Greater voluntary intakes of silage than of corresponding hay have been measured in sheep fed alfalfa (Peccatte and Dozias, 1998). They also reported a decrease in energy content and digestibility of the hay due to leaf losses during curing on the ground. Beaumont et al. (1998) noted a preference by sheep for ryegrass silage as opposed to the original crop fed as hay during the first half-hour following feeding, but the reverse during the second half-hour. However, Burns et al. (1993) reported no difference in DMI or DM digestibility by steers of switchgrass hay artificially dried or ensiled directly when harvested either in the late-boot or the fully headed stages of maturity despite wide differences in chemical composition. Conversely, Dulphy (1972) found sheep consumed greater amounts of timothy hay than of the corresponding silage cut in the late-boot stage. Morphology, abrasiveness, DM content, and chemical composition are some of the factors influencing feed consumption. Forage length is another contributing factor. Studies with cattle and sheep found that sequential decreases in chop length from 10 to 25 cm, to 5 to 15 cm, and finally to .5 to 1.8 cm increased grass silage intakes (Dulphy and Demarquilly, 1975; Deswysen et al., 1978). In the present study, the difference in forage chop length between hay (7 to 15 cm) and silage (1.5 to 4 cm), due to harvesting method, may partially explain the greater intake of silage.

Chewing Behavior. Steers spent an equal amount of time ingesting a greater amount of silage (.9 kg DM/d) than of hay while making fewer eating chews ($P < .10$; Tables 3 and 4). However, more time was spent ruminating ($P < .05$), and consequently more rumination chews were made ($P < .04$) and more boli ($P < .10$) were ruminated daily (Table 5) to process the greater amount of silage ingested. However, rumination efficiency (Table 3), defined as DMI (g/d)/rumination time (min/d), was not affected by diet. Total daily chewing time was greater for the silage ($P < .09$), whereas the number of jaw movements produced daily was similar between treatments. When expressed per kilogram of NDF intake, more eating chews were produced ($P < .02$) and more time was spent eating ($P >.03$) hay than silage. Conversely, no difference was observed for rumination time, number of rumination chews produced, and number of boli ruminated/kilogram of NDF intake. Therefore, eating behavior accounted for the greater total chewing time ($P < .10$) and total number of chews ($P < .01$) produced/kilogram of NDF intake on the hay diet. Rumination times approximated the upper values re-

Table 3. Eating and ruminating behavior of steers fed switchgrass hay or silage

	Preservation method			
Item	Hay	Silage	SE[a]	$P > F$
Chewing time, min/d				
Eating	321.6	306.1	5.6	.12
Rumination	494.8	558.7	15.8	.05
Total	816.4	864.8	15.5	.09
Chewing time, min/kg NDF intake				
Eating	82.2	70.2	2.6	.03
Rumination	125.0	128.4	3.5	.53
Total	207.2	198.6	2.9	.10
Eating rate, g DM/min[b]	16.8	20.4	.7	.03
Rumination efficiency, g DM/min[c]	10.8	11.0	.3	.58

[a]Standard errror from the GLM model.
[b]DM intake (g/d)/eating time (min/d).
[c]DM intake (g/d)/rumination time (min/d).

ported by Dulphy et al. (1980) and Kennedy (1985) and were fairly similar to those reported by Luginbuhl et al. (1989) with steers fed Coastal bermudagrass hay. Similar and greater rumination times have also been reported by Deswysen et al. (1987) and Teller et al. (1989) in growing heifers fed corn and grass silage, respectively, and by van Bruchem et al. (1991) in mature cows fed grass hay and wilted grass silage.

Steers ingested silage faster (g DM/min; Table 3) than hay ($P < .03$). Long-chopped hay is undoubtedly more resistant to mastication and microbial digestion than its corresponding green forage or silage. Under such conditions, steers would be expected to adapt their ingestive behavior to reduce feed to a particle size appropriate for bolus formation and subsequent deglutition (Luginbuhl et al., 1989). Therefore, the lower eating rate of the steers fed hay indicates that during ingestive mastication particle size reduction and incorporation of saliva for bolus formation took longer than for its corresponding silage that had been chopped to a much smaller length. Steers eating high-moisture forages masticate less extensively and do not swallow well-formed boli (D. S. Fisher, personal communication). Chopping forage to a decreased length also can increase eating rate (Voskuil and Metz, 1973; Kim et al., 1994) and decrease the number of eating bites (Piatkowski et al., 1977). In addition, results from this study are in agreement with Chase et al. (1976), who found increased feed intake to be associated with an increased rate of eating by Holstein steers.

Although restricted by their buccal anatomy, relative to browsers that possess a split upper lip and a narrower mouth, cattle can sort long feed using their tongues, ingesting first the more nutritious parts (i.e., leaves) and progressively ingesting coarser material, particularly with dry forage (Luginbuhl, unpublished observations). Steers sorted the long-chopped hay, as evidenced by the difference between the NDF concentration of the hay fed (74%) and its corresponding orts (80%). Conversely, little sorting occurred when steers were fed silage (fed: 71.4% NDF; orts: 72.4% NDF). Therefore, minimal sorting during eating and a shorter particle length also may be responsible for the higher DMI and higher intake rate of the silage. Hay consumption also may have been limited by the amount of saliva needed to moisten the forage for swallowing. In addition, steers spent more time eating hay/kilogram of NDF intake than silage (Table 3); we surmise that total saliva out-

Table 4. Eating and rumination chews in steers fed switchgrass hay or silage

	Preservation method			
Item	Hay	Silage	SE[a]	$P > F$
No. of chews/d				
Eating	21,025	19,054	640	.10
Rumination	29,014	33,103	920	.04
Total	50,039	52,157	1,148	.26
No. of chews/kg NDF intake				
Eating	5,383	4,381	199	.02
Rumination	7,333	7,572	168	.37
Total	12,716	11,953	124	.01
No. of chews/min eating time	65.1	62.3	1.0	.13
No. of chews/min rumination time	58.8	59.2	.69	.71

[a]Standard error from the GLM model.

Table 5. Ruminated boli, boli characteristics, and fecal particle size in steers fed switchgrass hay or silage

	Preservation method			
Item	Hay	Silage	SE[a]	$P > F$
Ruminated boli, no./d	455.0	520.5	22.1	.10
Ruminated boli, no./kg NDF intake	115.2	119.3	4.5	.14
Bolus duration, s	65.2	64.7	1.1	.76
Intercycle time, s[b]	5.0	5.4	.1	.05
No. of chews/bolus	63.9	63.7	1.3	.94
No. of boli/min rumination time	.92	.93	.01	.64
Fecal particle size, μm	337.2	321.1	5.2	.03

[a]Standard error from the GLM model.
[b]Duration of the interval between rumination cycles (swallowing and regurgitation).

put, ruminal buffering capacity, and ruminal pH were higher for animals consuming hay.

No difference in the number of chews produced per minute of eating or rumination time was detected (Table 4). Steers seemed to chew somewhat faster per minute of activity while eating. Bolus duration, number of chews per bolus ruminated, and number of boli produced per minute of rumination time (Table 5) were similar between preservation methods, whereas the intercycle time was slightly longer for the silage ($P < .05$). The number of boli regurgitated daily is similar to that noted in a report by Bae et al. (1981) studying Holstein cows, whereas Deswysen et al. (1987) reported greater values for growing heifers fed corn silage. Similar numbers for ruminated boli/kilogram of NDF intake, bolus duration, number of chews/bolus, and intercycle time were reported by Luginbuhl et al. (1989). Intercycle time was comparable to values reported for rams by Deswysen and Ehrlein (1981).

Ulyatt et al. (1986) indicated that the contributions of ingestive mastication and rumination to particle size reduction were similar with fresh forage diets, but that rumination made a much larger contribution to particle size reduction with dried forage diets. In the present study, differences in forage chop length, post-harvest treatment, and percentage DM between treatments affected DMI and chewing behavior. Rumination time/kilogram of NDF intake and number of rumination chews/kilogram of NDF intake were similar between diets, whereas steers produced a greater number of eating chews/kilogram of NDF intake and spent more time eating hay (min/kg NDF intake) but at a lower rate (g DM/min; Tables 3 and 4). This shift in chewing behavior nevertheless resulted in a greater fecal particle size ($P < .03$) for steers fed hay (Table 5). Even when chopped, switchgrass hay had coarse leaves and rough and rigid stems. Switchgrass ensiled directly, apart from being of shorter length, was more pliable because

Table 6. Patterns of chewing behavior in steers fed switchgrass hay or silage

	Preservation method			
Item	Hay	Silage	SE[a]	$P > F$
Meals				
No./d	6.6	7.9	.5	.13
Duration, min	53.2	42.1	3.1	.06
Duration of main meal, min[b]				
Morning	102.2	91.3	2.9	.06
Evening	136.7	108.8	9.4	.10
Morning plus evening	238.9	200.1	9.5	.05
Duration of main meal, % of total eating time				
Morning	32.0	30.2	1.4	.41
Evening	42.3	35.9	2.0	.09
Morning plus evening	74.3	66.1	1.6	.02
Rumination periods				
No./d	11.8	13.5	.2	.008
Duration, min	42.9	41.7	1.6	.64
Latency time, min[c]				
Morning	38.3	24.1	3.9	.06
Evening	24.1	22.8	3.9	.83

[a]Standard error from the GLM model.
[b]Meals initiated by feed distribution. Animals were fed at 0900 and 1600.
[c]Duration of the interval between the end of the main meal and the onset of rumination.

plant cells were well hydrated, presumably resulting in more disruption and damage of cell walls and cell structure during ingestive mastication.

Patterns of Chewing Behavior. The number of daily meals was similar between diets (Table 6), but steers fed silage had meals of shorter duration ($P < .06$), possibly due to lower ruminal pH resulting from lower saliva production. Steers spent more time eating hay than silage during both the morning ($P < .06$) and evening ($P < .10$) main meals. Summation of morning and evening main meals was 38.8 min longer for steers eating hay than for those eating silage ($P < .05$). Morning and evening meals were very important activities, accounting for 70% of total eating time. In addition, feed distribution always initiated eating. These results are in agreement with Dulphy et al. (1980), who indicated that meals following feeding are the longest, lasting between 1 and 3 h. The morning main meal accounted for the same percentage of total eating time, whereas the evening main meal accounted for less total eating time ($P < .09$) for the silage. Added together, morning and evening main meals accounted for 8.2% less total eating time on silage than on hay ($P < .02$). Steers fed silage had more rumination periods than those fed hay ($P < .008$), whereas the mean duration of rumination periods did not differ. Feeding timothy hay and its corresponding silage to sheep, Dulphy (1972) reported similar trends for the number of meals, the average duration of meals, and the duration of meals following feed distribution but opposite effects for the number of rumination periods. In that study, the lower consumption of silage than of hay may explain the concomitant decrease in the number of rumination periods. A higher number (14.8) of rumination periods of shorter lengths (36.7 min) were reported by Deswysen et al. (1987). According to Dulphy et al. (1980), periods of rumination (10 to 17/d) are separated by spontaneous meals (3 to 8/d). Diet influenced morning latency time ($P < .06$), whereas evening latency time was similar for the two diets. Much shorter latency times (3.8 to 11.3 min) have been reported (Deswysen et al., 1987). In the present study, the shorter morning latency time seemed to indicate that the particle breakdown process, accompanied by increased VFA production and concomitant pH change, started sooner in steers fed silage.

Implications

Feeding ensiled switchgrass cut at a smaller chop length than the same material cured as hay can alter chewing behavior by increasing eating rate and total feed consumption by steers, and could possibly result in increased animal performance.

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